Racial disparities in municipal water and sewer access in western North Carolina

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Jacqueline MacDonald Gibson, Advisor

Abstract

In the 21st Century, there is still observable racial division in communities of the southern United States. In North Carolina, though institutional discrimination has long been outlawed, residual segregation in housing patterns persists. Descendants of freed slaves now live in extra-territorial jurisdictions (ETJs) of the small, southern towns their ancestors settled outside of, which are subject to the adjacent municipality's zoning and land-use statutes but have no political representation. Communities within an ETJ are not guaranteed municipal water or sewer service by a municipality; if not annexed, these areas must rely on wells and septic systems as an alternative. Should septic systems fail and zoning or land use ordinances prevent timely or affordable replacement, local groundwater contamination would pose a threat to public health. To investigate the role of race in access of municipal services by ETJ populations in Burke and Catawba Counties of NC, we apply logistic regression to tax parcel utility and Census demographic and socioeconomic data aggregated using a geographic information systems (GIS) approach. Comparison of regressions at each county and utility pairing revealed complex relationships between census block black population percentage, socioeconomic indicators parcel value and block group median household income, and ETJ block residential housing density. Regression trends agreed at low and median housing density scenarios in both counties but disagree at high housing density in Burke County. Race could play a role in municipal water and sewer service access in Burke and Catawba County ETJs, but the magnitude and direction of impact greatly varies between socioeconomic and housing density scenarios. Specific analysis of the historical urban planning and zoning designations of areas of interest within these ETJs would be more illuminating in determining whether or not these communities still feel the influence of race-based segregation. Future work involving Hispanic or non-white populations, as well as using well or septic utility services as proxies for lack of municipal service, would be of great interest in NC and the South overall.

Introduction

Recent studies have suggested that "racial residential segregation remains a fact of life in the South" in the 21st Century (Parnell et al., 2004). In North Carolina specifically, small town governments have historically refused blacks many basic rights through Jim Crow laws and other discriminatory behavior (Johnson et al., 2004). Despite institutional discrimination being outlawed nearly half a century ago, the residual segregation in housing patterns persists (Johnson et al., 2004).

The post-Civil War settlement patterns of freed slaves show that most took up residence around the edges of communities of the South (Johnson et al., 2004) in 'fringe' populations and now fall within extra-territorial jurisdictions (ETJs). Property within an ETJ is subject to all land-use, permitting, and zoning regulations of the local NC municipality (G.S. 160A). However, residents have no political representation within the municipal government (Parnell et al., 2004). While communities within an ETJ are available to be annexed into a governing municipality, some neighborhoods frequently are denied annexation (Aiken, Lichter et al., Parnell et al., Johnson et al.).

Over time, this has resulted in the "underbounding" of black communities in ETJs of the South (Parnell et al., 2004). One consequence of underbounding is that an unincorporated property within an ETJ may not be provided municipal water and sewer service, leaving its residents to rely on septic tanks and well water. A municipality can rezone ETJ land at any time and leave residents effectively unable – due to regulations and monetary cost – to replace or repair failing septic systems (Johnson et al., 2004).

Such actions increase the risk of waterborne pathogens from human fecal matter spreading to local groundwater, possibly contaminating private wells. People living in residences that draw drinking water from wells, rather than piped municipal water, may be at risk of infection (Johnson et al., 2004). The presence of certain bacteria in untreated groundwater at any level above zero can be associated with an increase in acute gastro-intestinal diseases (Zmirou et al., 1987), and density of septic systems has been associated with endemic diarrheal illness (Borchardt et al., 2003). Furthermore, rate of reported disease outbreaks with private water systems has increased, while the opposite is true for public water systems (Craun et al., 2010).

Rezoning, lack of utility service, and no political representation may also result in excluded communities being "systematically underdeveloped" and having lowered property values (Gilbert, 2013). These economic disadvantages can grow over time; missing infrastructure and development act as significant disincentives for businesses or schools to be built (Gilbert, 2013). However, underdeveloped and inexpensive land creates an incentive for the construction of locally unwanted land uses, like wastewater treatment plants (Gilbert, 2013). As time goes on, communities once denied annexation due to racial discrimination may now face it on an economic basis because of these negative externalities.

Previous studies of racial exclusion in southern towns have discussed this possibility. Aiken concluded that towns of Mississippi's Yazoo Delta with majority-white governments chose to selectively exclude newly-built black residential neighborhoods while also admitting that "it is plausible to assume that municipalities oppose the annexation…not for racial reasons but because the areas would be economic liabilities" (Aiken, 1987). Similarly, Lichter et al. (2007) established that "white communities [of the South] are substantially less likely to annex black fringe areas than are more racially diverse communities" but cautioned that there is no "simple or straightforward story of widespread racial exclusion in the South…[we cannot] eliminate all possible non-racial explanations that may explain our results" (Lichter et al., 2007).

Differing methodologies in previous studies, possibly brought on by the lack of useful comprehensive data (Gilbert, 2013), make comparison of results difficult. For instance, Lichter et al. (2007) used Census data from 1990 and 2000 to identify annexed neighborhoods in a broad analysis, analyzing only Census blocks contiguous to 1990 town boundaries rather than all area available for annexation. However, Johnson et al. (2004) and Parnell et al. (2004) combined Census information as well as public waterlines, sewerlines and ETJ files from specific towns chosen for investigation; although the study covered all ETJ land, using public water and sewer line data to estimate communities with service introduces some inaccuracy.

Furthermore, establishing proof of racial exclusion is complicated by the paucity of studies done (Gilbert, 2013). Overall, few towns of the South have been rigorously studied for evidence of racial exclusion. To be able to make concrete conclusions, more empirical data must be collected regionally and analyzed more uniformly.

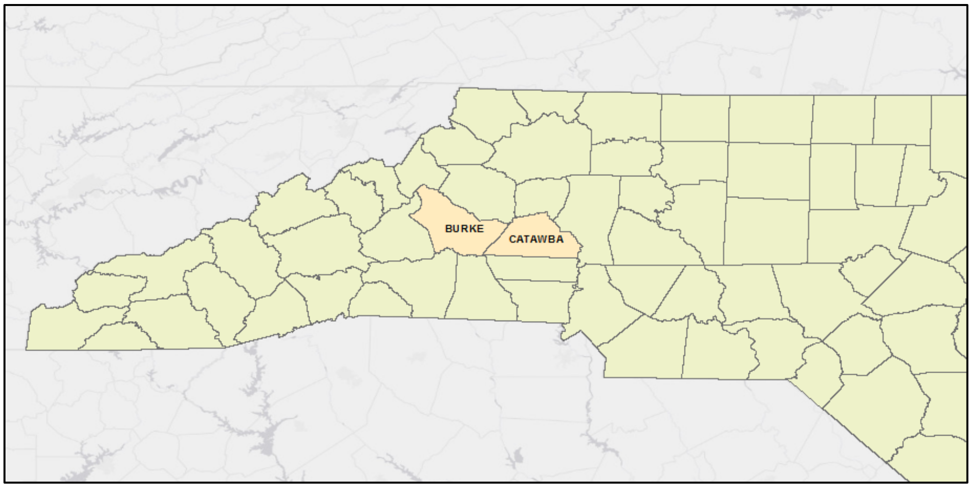

Figure 1: Burke and Catawba Counties

The purpose of this study is thus to improve upon previous methods for identifying racial exclusion by limiting the geographical area of study and using data sources of higher spacial precision and seek to supplement the regions of the South studied to this point. Specifically, this study will assess the extent of racial exclusion from municipal water and sewer service in Burke and Catawba Counties of North Carolina (**Figure 1)**, using geographic information systems (GIS) and statistical analyses. The results will help to paint a larger picture of underbounding and persistent racial exclusion in the southeastern US.

Methods

To analyze the potential role of race in access to municipal utility service, we conducted a logistic regression analysis. The dependent variable was a binary indicator of whether or not each residential property, or tax parcel, in the ETJ had access to the utility service of interest (water or sewer). Additional explanatory variables considered were housing density and two measures of socioeconomic status: total property value and median household income. Data sources of each variable and further explanation of the logistic regression method are given below. All data were provided either in GIS shapefile or spreadsheet format. Spatial manipulation and statistical evaluation of data sources was done using both the ESRI ArcGIS software package and R programming language scripts.

ETJ Location Selection

GIS shapefiles of county ETJ boundaries (**Figure 2**) were obtained from the Burke[1] and Catawba[2] County GIS and Mapping Departments. The shapefiles were used to geographically limit our analysis to only tax parcels within ETJ boundaries.

[1] Scott Black (Burke County GIS/Mapping). Email. Spring 2014.
[2] Kate Sturgeon (Catawba County GIS/Mapping). Email. Fall 2014.

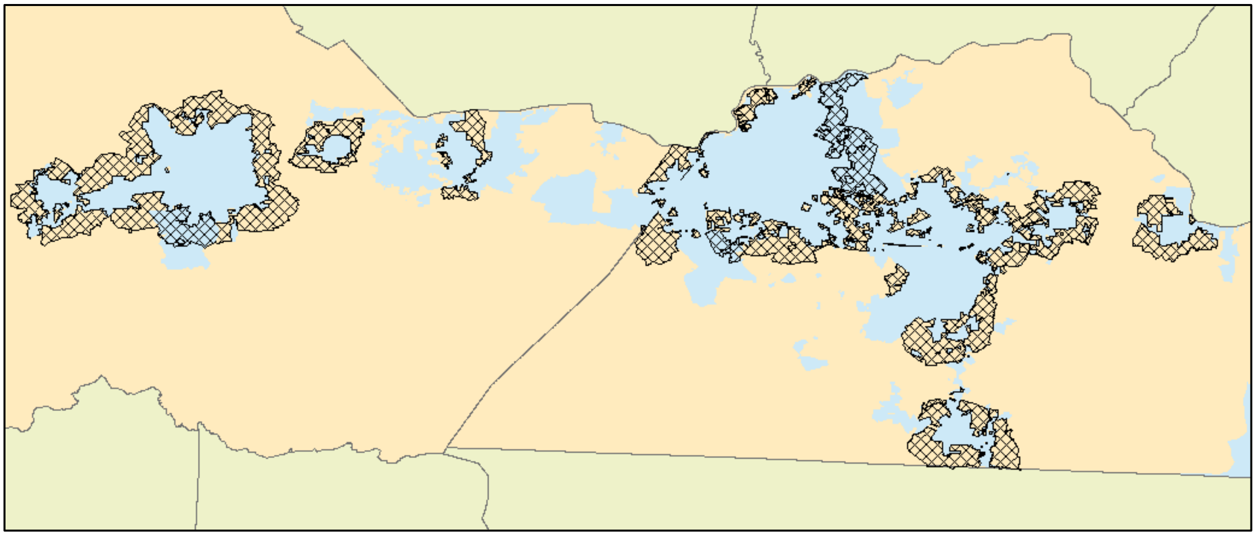

Figure 2: Burke (left) and Catawba (right) County ETJs (black cross-hatch) and 2010 Census places (light blue)

Water and Sewer Access Database Construction

Data on municipal water and sewer access were obtained from Burke[1] and Catawba[2] County tax parcel datasets. Each taxed property in each county is spatially represented in that county's shapefile and described by an accompanying attribute table, containing a utility code, "UTIL" in Burke County and both "utilities_" and "utilities1" in Catawba County, indicating whether or not the property had access to water or sewer service, respectively. For each parcel, two new binary attribute fields, "PubWater" and "PubSewer", were created. If a parcel has municipal water (sewer) access according to the utility code fields, then the "PubWater" ("PubSewer") field is filled with a value of 1. If the property does not have access, then it is given a value of 0.

The tables also contain land value, building value, and zoning attributes for each parcel. In both counties, total property value is calculated for every parcel by summing land and building value. The zoning attribute field was directly used to isolate residential parcels in Burke County; all non-residential parcels were removed from our analysis. Because Catawba zoning information was given in a different shapefile than the utility information, residentially zoned parcels were selected from one shapefile and spatially joined to the other shapefile containing utility access fields. Any parcels not present in both shapefiles were excluded from the analysis.

Demographic Data Extraction

From the University of Minnesota's National Historical Geographic Information System[3], a census block shapefile and corresponding tables containing total and black block populations of North Carolina were obtained. After joining the shapefile and table, separate shapefiles were generated for both Burke and Catawba County separately to minimize computational strain in

[3] Minnesota Population Center. National Historical Geographic Information System: Version 2.0. Minneapolis, MN: University of Minnesota 2011.

further analysis. An NHGIS table of the median household income of NC block groups was also retrieved and disaggregated to the block level using a common attribute field to join the datasets.

Each county block shapefile, with population and income attributes, was spatially joined to the corresponding county parcel shapefile containing all previously calculated fields. Each parcel was assigned to the block in which its geographic centroid fell. The resultant shapefiles contained a single polygon of each parcel, the parcel's property value, water, and sewer service indicator columns, and any population and income data of the associated census block and block group. If a selected parcel fell within a block with a population of 0, it was removed from analysis. When joining block-level data to parcel-level shapefiles, ArcGIS was also used to calculate the housing density of residential ETJ parcels – the number of ETJ residences joined to a block divided by the area (square kilometers) of the block.

Logistic Regression Analysis

Using R programming language and the 'glm' code package, logistic regression was performed upon the resultant table in an effort to determine if race is associated with a lack of municipal utility service, independent of property value, block group median household income, and block housing density.

$$\log\left(\frac{p(x)}{1-p(x)}\right) = \beta_0 + \beta_1 R + \beta_2 S + \beta_3 H + \beta_4 RS + \beta_5 RH + \beta_6 SH + \beta_7 RSH + \varepsilon$$

Equation 1: Logistic model, x being a particular parcel and p(x)
being the probability of x having water (sewer) service.
R = race percentage of the population of the census block of parcel x
S = total property value or household income of parcel x
H = housing density of the census block of parcel x

The logistic probability of a parcel having municipal water (sewer) service is determined by a linear function of minority race (black) population percentage, socioeconomic (parcel value or household income), and housing density terms, plus different interaction terms between the three variables (**Equation 1**).

Thirteen variations of this regression were fit to the data, all of which contained a race demographics term (black block population percentage), a socioeconomic term (total property value or median household income), a housing density term, and 0-4 interaction terms (**Table 1**).

Regression	Intersection Terms Included
0a	All
0b	None
1	Race-Socioeconomic (RS)
2	Socioeconomic-Housing Density (SH)
3	Race-Housing Density (RH)
4	RS, RH, SH
5	RS, RH
6	RH, SH
7	RS, SH
8	Race-Socioeconomic-Housing Density (RSH)
9	RS, RH, RSH
10	RS, SH, RSH
11	RH, SH, RSH

Table 1: Regression variations

Model Selection Procedure

The final regression model was selected based on the Aikake Information Criterion (AIC). We developed two different regression models to examine associations between race and utility service. The first model included three explanatory variables (percent black, median income, and housing density) along with one-way interactions between race and the other two independent variables. The second model was chosen by trying 26 different versions of **Equation 1** involving two different measures of socioeconomic status (median income or property value) and all possible one- and two-way interactions among the explanatory variables (**Table 1**). Among these 26 models, the model with the lowest AIC value was chosen. The two models – the model with median income and only interaction terms involving race, regression 5, and the model with the lowest AIC – were then analyzed for patterns concerning the effects of race on water and sewer service access.

Results

Tax Parcel Distribution

In Burke County (**Table 2**), only 26.89% (949 total) of residential ETJ parcels have municipal sewer service, compared to 5.33% (243 total) in Catawba County (**Figure 4c**). The difference in water service between counties (**Figure 4b**) is not as drastic, 68.01% (2400 parcels) in Burke to 59.80% (2727) in Catawba (**Figure 3**).

Geographic Level	Burke	% of Total	Catawba	% of Total
County	57856	100.00	86680	100.00
Residential	30711	53.08	56032	64.64
ETJ	6001	10.37	10517	12.13
ETJ, Residential	3529	6.10	4561	5.26
ETJ, Res, Water	2400	4.15	2727	3.15
ETJ, Res, Sewer	949	1.64	243	0.28

Table 2: Number of tax parcels at each geographic level

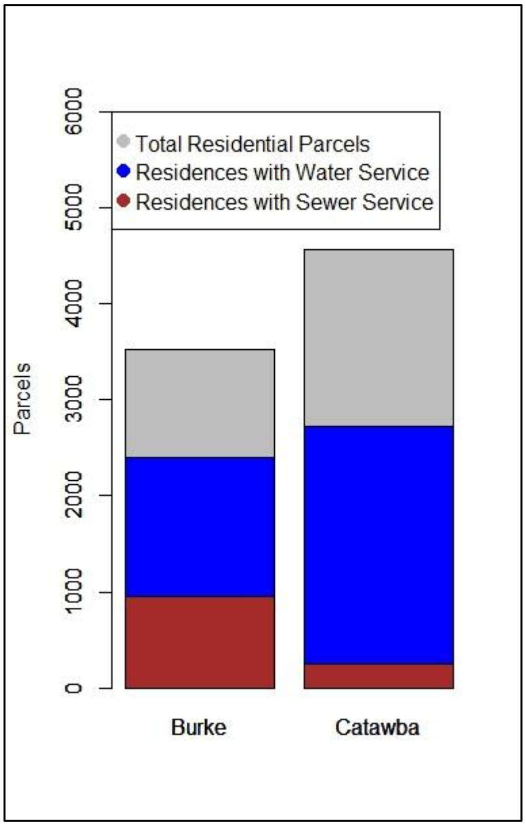

Figure 3: ETJ residential parcel services

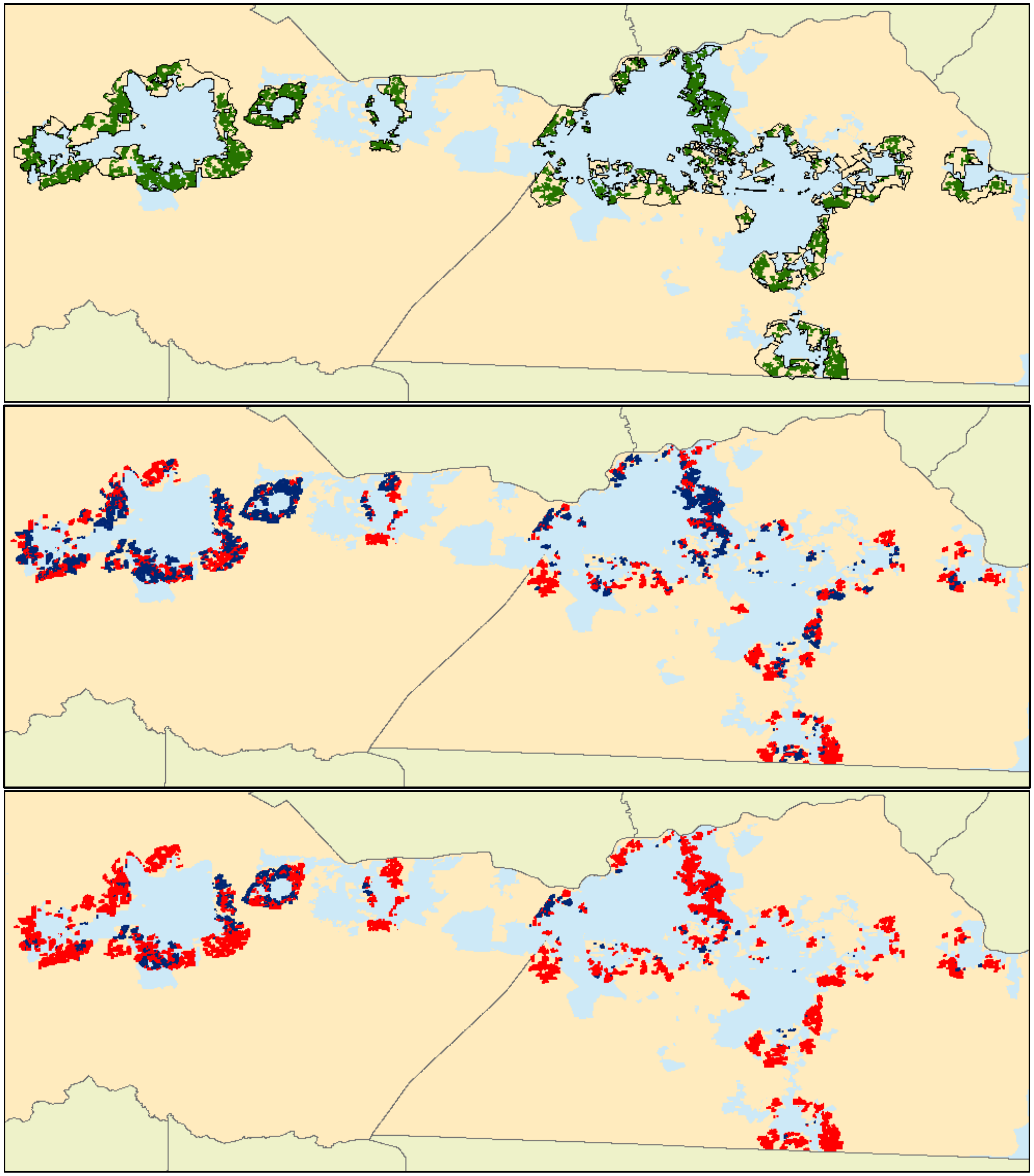

Figure 4: (a) residential ETJ tax parcels (green) and boundaries (black).
(b) municipal water service for each parcel.
(c) municipal sewer service.
Dark blue indicates municipal service, red indicates no service.

Socioeconomic Indicators

Along with total parcels, property values at different geographic extents varied greatly (**Table 3**). Burke County residential ETJ parcels had a median value of $99,968, more than the $91,024 median value of all county residential properties. The same relationship is reversed in Catawba County, $109,000 to $117,800. Burke County parcels have lower median values than Catawba at each geographic level.

Residences in Burke County ETJ that have municipal sewer service alone, or municipal water and sewer service together, median total values - $94,875 and $94,902 respectively - significantly below the median value of all ETJ residences, $99,968, or those with only water service, $99,862. The opposite is true in Catawba County; residential ETJ parcels with sewer service, or water and sewer service, have a median value of $129,000 while all residences in the ETJ have a median value of $109,000. Block averages of parcel value for ETJ blocks can be found below in **Figures 5 and 6**.

Geographic Level	Burke	Catawba
All Residential	$91,024	$117,800
ETJ, Residential	$99,968	$109,000
ETJ, Res, Water	$99,862	$112,000
ETJ, Res, Sewer	$94,875	$129,000
ETJ, Res, Both	$94,902	$129,000

Table 3: Median total parcel value (USD)

Median household income, henceforth referred to as income, was also used as an indicator of socioeconomic status. Though the spatial resolution of income was coarser than that of parcel value – census block group level compared to parcel level – differences in income levels were evident across the ETJs of both Burke and Catawba County.

Block group income medians reflect the same difference in economic status between the counties as parcel value (**Table 3**). Catawba County median income (**Table 4**) of block groups containing a residential ETJ parcel was 25% greater than the respective median incomes in Burke County. When comparing median incomes for all block groups in either county, this figure rose to 28%.

Geographic Level	Burke	Catawba
County	$34,560	$44,517
ETJ	$34,958	$43,556

Table 4: Median household income (USD)

Residential ETJ housing density also differed between the ETJs of either county. Burke County census blocks containing at least one ETJ residential parcel had a median housing density – residentially-zoned ETJ parcels per square km – of 63.66, while Catawba ETJ blocks had a median housing density of 76.29.

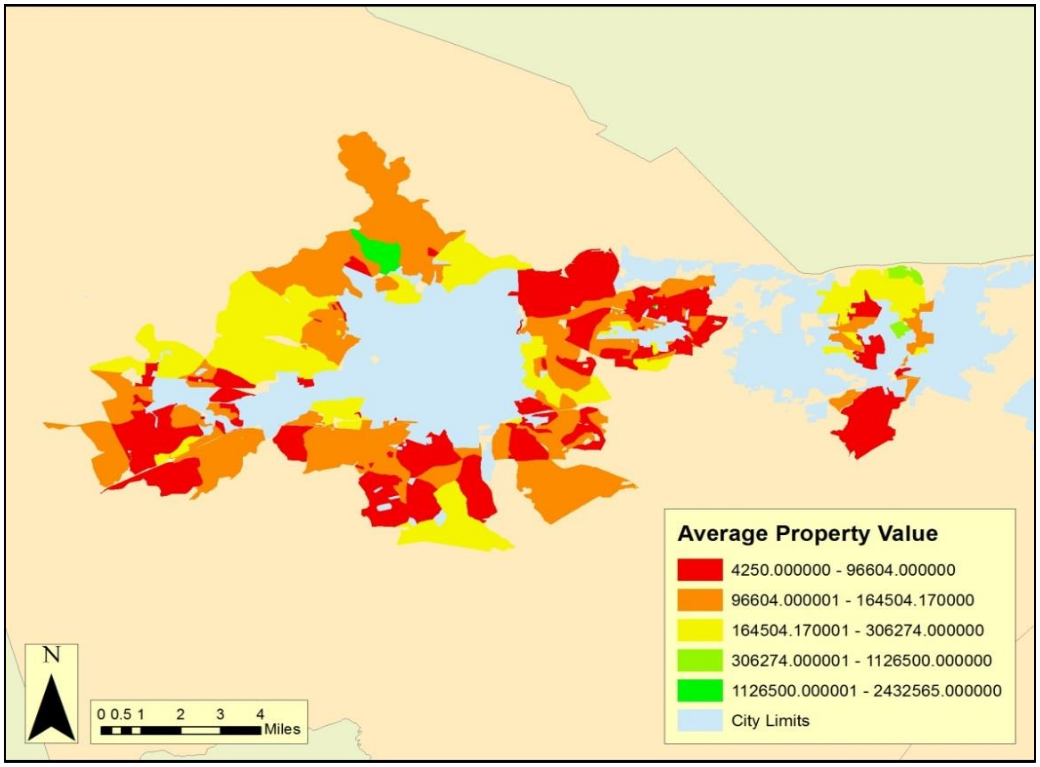

Figure 5: Burke ETJ block property values

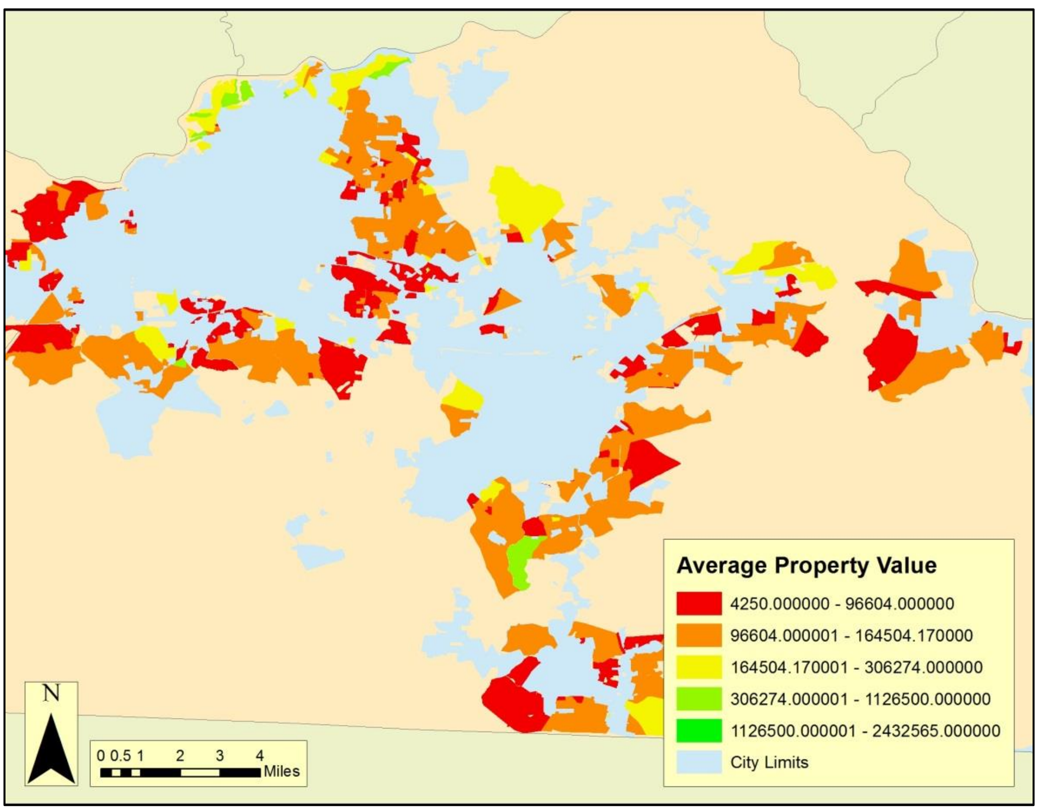

Figure 6: Catawba ETJ block property values

Race Demographics

There were also marked differences in block racial composition (**Table 5**). Compared to the rest of the county, residential ETJ census blocks in both counties had below county-level black population percentage.

County	Geographic Level	Blocks	% of Total		Total Population	Black	% Black of Total
Burke	County	3,095	100.00		90,912	6,012	6.61
	ETJ	556	17.96		22,139	1,930	8.72
	ETJ, Residential	325	10.50		18,917	1,065	5.63
Catawba	County	5,199	100.00		154,358	13,041	8.45
	ETJ	1,277	24.56		35,811	2,900	8.10
	ETJ, Residential	381	7.33		19,452	1,193	6.13

Table 5: Census block count and population demographics

Logistic Regression

County	Utility	Regression	AIC	% Difference
Burke	Water	5 (income)	4,320.5	
		2 (income)	4,291.1	0.68
	Sewer	5 (income)	3,903.1	
		0a (income)	3,894.6	0.22
Catawba	Water	5 (income)	5,197.9	
		7 (parcel value)	5,096.9	1.94
	Sewer	5 (income)	1,793.4	
		6 (parcel value)	1,789.3	0.23

Table 6: Regressions compared at each county-utility pairing.
% Difference represents the percent difference between regression 5 and the regression of lowest AIC for each county-utility pair.

There was only marginal difference in AIC between regression 5 and the regression of lowest AIC for each county-utility pairing (**Table 6**). Each of these regressions is presented in three plots, all with black population percentage as the independent variable and probability of municipal service as the dependent variable. All plots display three trends, each with a set socioeconomic level – 5th, 50th (median), or 95th percentile of the chosen county ETJ's residential parcel values or median household income levels. The first plot, on the left, gives these three trends at the 5th percentile of ETJ block housing density for said county. The middle plot does the same at the 50th housing density percentile, and the right plot at the 95th percentile.

Burke – Water Service

Displayed regression results of the Burke County and municipal water service pairing are with respect to median household income. Regression 2 was the regression of lowest AIC.

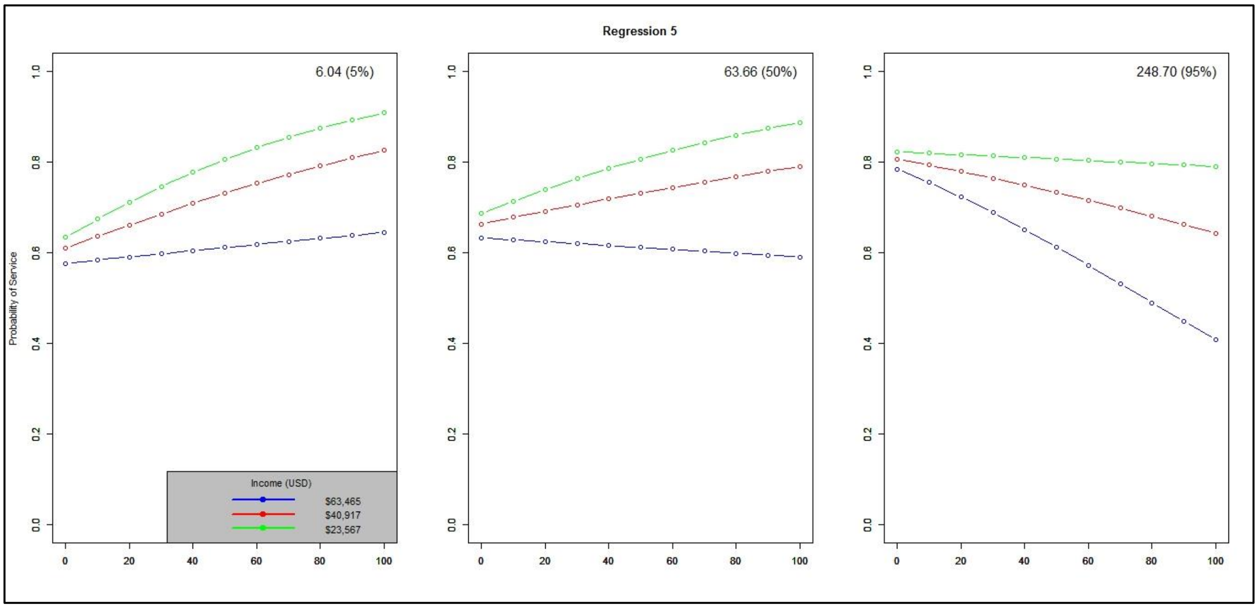

Figure 7: Regression 5 results of probability of water service in Burke County
Housing density of each plot (and percentile) given at top right.

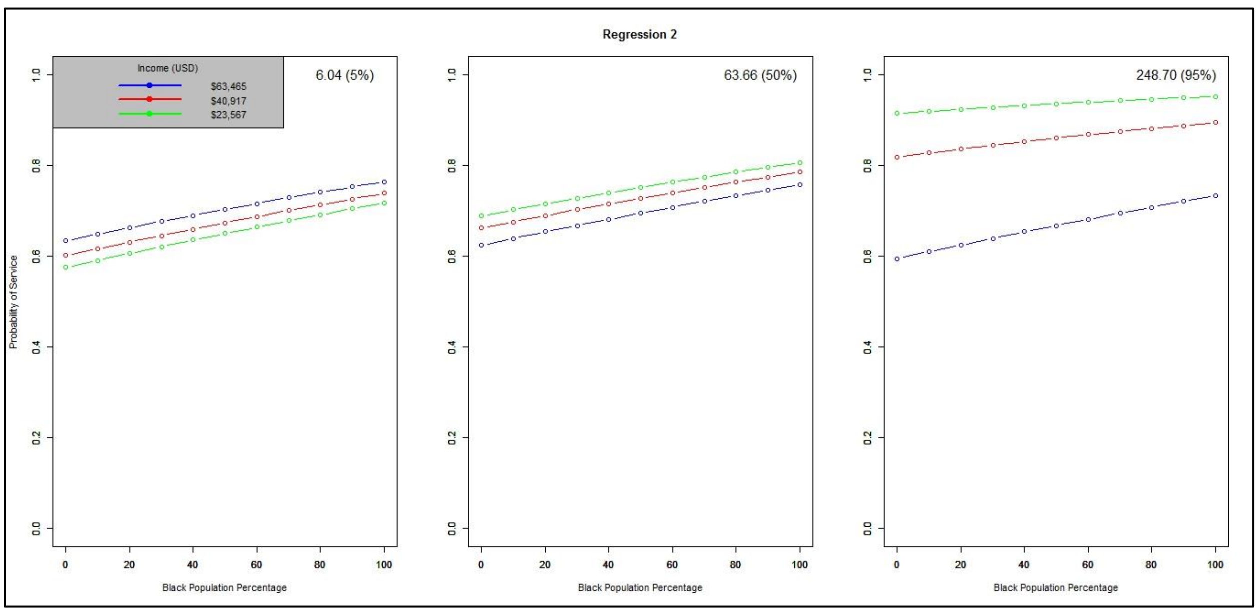

Figure 8: Regression 2 results of Burke County water service probability,
also regression of lowest AIC.
Housing density of each plot (and percentile) given at top right.

Both regression 5 (R5, **Figure 7**) and regression 2 (R2, **Figure 8**) show differences in water service probability trends with change in housing density. A very high housing density widens the disparity in service between levels of income for R2. An increase in R2 percent black population is positively associated with an increase in water service across all income and housing density levels; R5 shows decreases in service when housing density is in the 95th percentile.

Term	Regression 5		Regression 2	
Race (R)	**2.66E+00**	4.37E-02	**6.28E-01**	1.15E-01
Socioeconomic (S)	**-6.06E-06**	7.32E-02	**7.51E-06**	6.38E-02
Housing Density (H)	**4.05E-03**	3.45E-11	**1.40E-02**	1.09E-11
RS Interaction	**-3.66E-05**	2.02E-01	**-**	-
RH Interaction	**-8.05E-03**	2.77E-01	**-**	-
SH Interaction	**-**	-	**-2.31E-07**	8.02E-08
RSH Interaction	**-**	-	**-**	-
Intercept	**6.71E-01**	1.62E-05	**7.77E-02**	6.81E-01
AIC	**4320.5**		**4291.1**	

Table 7: Coefficients (left column) and p-values (right column) of each regression used in the Burke County – water pairing. Statistically significant p-values ($p < 0.05$) in red.

Of the terms in R2, only the housing density term and the interaction term between socioeconomic and housing density factors were statistically significant (**Table 7**). The R2 service rate of change – change in probability of municipal service over change in black population percentage – is consistent across all socioeconomic and housing density levels. As housing density increases, there is a incremental drop in the probability of service at high incomes, which comes from the R2 interaction term overwhelming all other terms in the regression, but the service rate of change remains positive as the R2 race term is positive..

Race and housing density terms of R5 were also significant. R5 service rate of change becomes negative at 95th percentile housing density, controlled by the race-housing density (RH) and race-socioeconomic (RS) interaction terms; the negative coefficient of the RH and RS terms ensures a drop in service probability as R and H increase, impacting probability more than all other terms with positive coefficients. Lower predicted service is also associated with higher socioeconomic status, unlike in R2.

Burke – Sewer Service

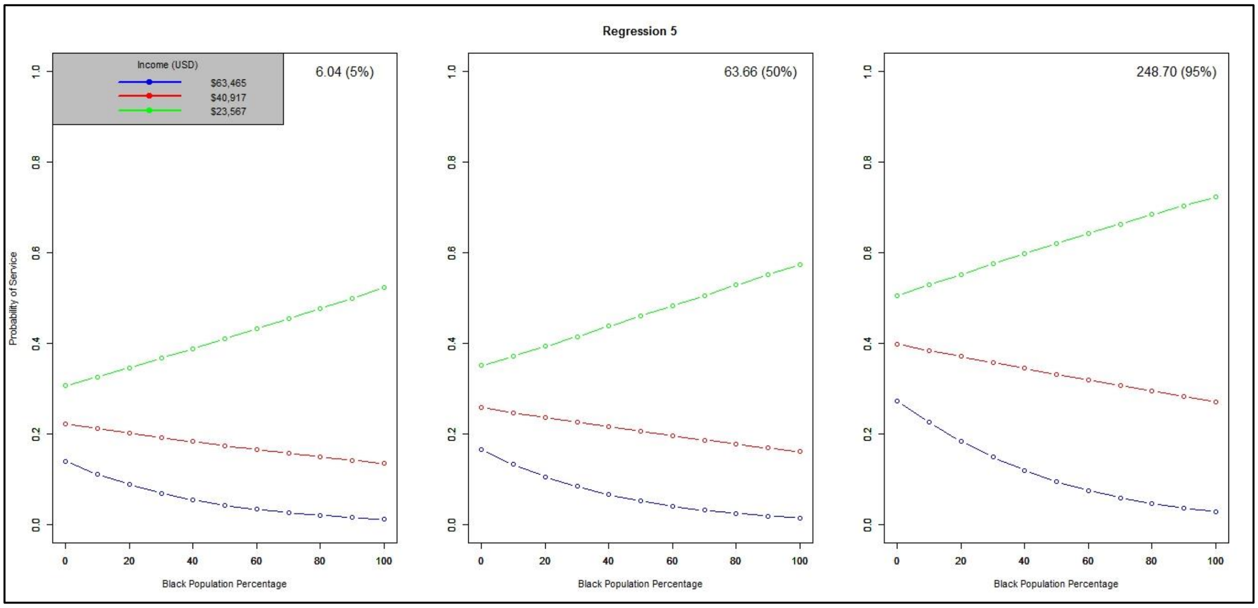

Figure 9: Regression 5 results of probability of sewer service in Burke County
Housing density of each plot (and percentile) given at top right.

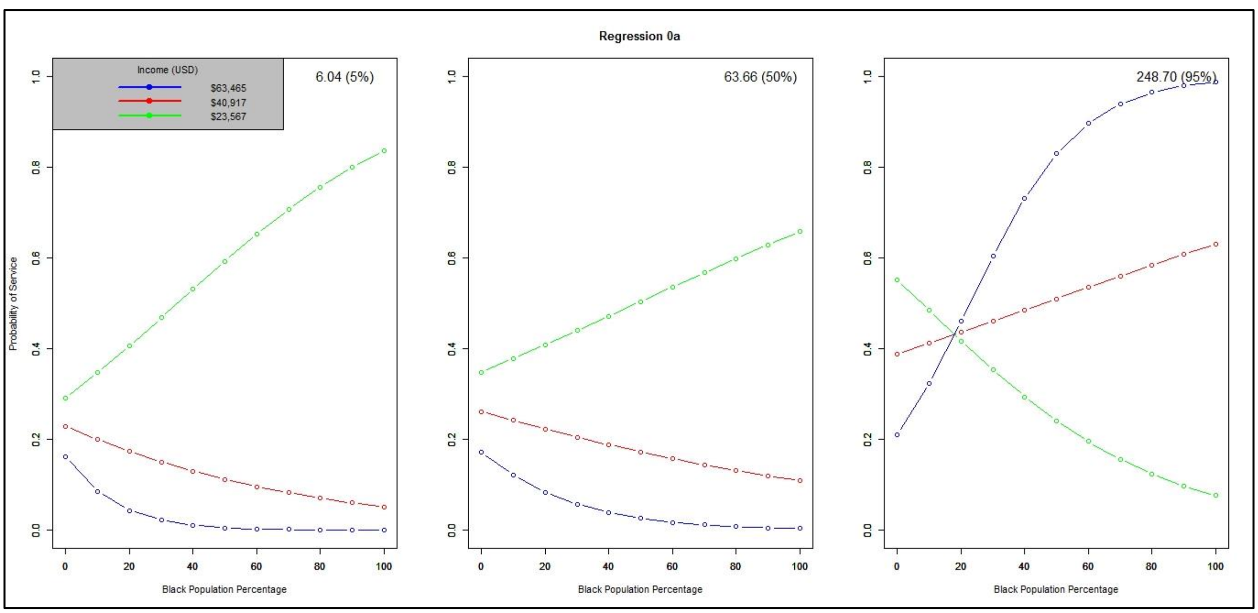

Figure 10: Regression 0a results of Burke County sewer service probability,
also regression of lowest AIC.
Housing density of each plot (and percentile) given at top right.

Burke County municipal sewer service with respect to income was best modeled by regression 0a (R0a, **Figure 10**), the regression of lowest AIC, with all 4 interaction terms. Regressions 0a and 5 (R5, **Figure 9**) both associate a drop in sewer service with a rise in black population percentage for households with median or 95th percentile income and housing density of the 50th percentile or less. These housing density thresholds also show a notable rise in service probability at the 5th percentile income level (left, center plots).

The models disagree when housing density is high; the 95th percentile of housing density shows a drop in sewer service at the 5th percentile income level as black population percentage increases in regression 0a, but the opposite in regression 5. Regression 5 trends appear relatively unaffected by housing density change, while regression 0a sees a complete inversion in trends as housing density approaches the maximum observed values within Burke County ETJs.

Term	Regression 5		Regression 0a	
Race (R)	**2.96E+00**	1.69E-02	**8.67E+00**	3.08E-05
Socioeconomic (S)	**-2.52E-05**	8.18E-11	**-1.86E-05**	5.04E-04
Housing Density (H)	**3.46E-03**	6.41E-12	**6.36E-03**	5.18E-04
RS Interaction	**-8.71E-05**	1.05E-02	**-2.55E-04**	2.80E-05
RH Interaction	**1.35E-04**	9.84E-01	**-6.60E-02**	1.03E-03
SH Interaction	**-**	-	**-7.88E-08**	7.67E-02
RSH Interaction	**-**	-	**1.88E-06**	4.63E-04
Intercept	**-2.42E-01**	1.39E-01	**-4.74E-01**	3.06E-02
AIC	**3903.1**		**3894.6**	

Table 8: Coefficients (left column) and p-values (right column) of each regression used in the Burke County – sewer pairing. Statistically significant p-values ($p < 0.05$) in red.

Race, income, housing density, and the RS interaction were statistically significant terms in R5 for sewer service. The RS and S terms for R5 have negative coefficients, resulting in a negative service rate of change at high R and S scenarios, observable in all R5 plots. However, low S trends (**Figure 9**, green) have positive service rate of change due to small S and RS terms relative to the R, H, and RH terms.

On the other hand, all R0a terms were significant except the income and housing density (SH) interaction (**Table 8**). The similar behavior of R0a to R5 at low and median housing density levels can be attributed to alike coefficients between terms; only the R0a RH interaction term has different coefficient sign than that of R5. This difference, and the addition of an RSH interaction term, primary driver of the differences between R0a and R5 at high housing density – high R, H, and S values mean a very large RSH term, resulting in a positive service rate of change (**Figure 10**, blue and red) despite the negative effect of all interaction terms in R0a.

Catawba – Water Service

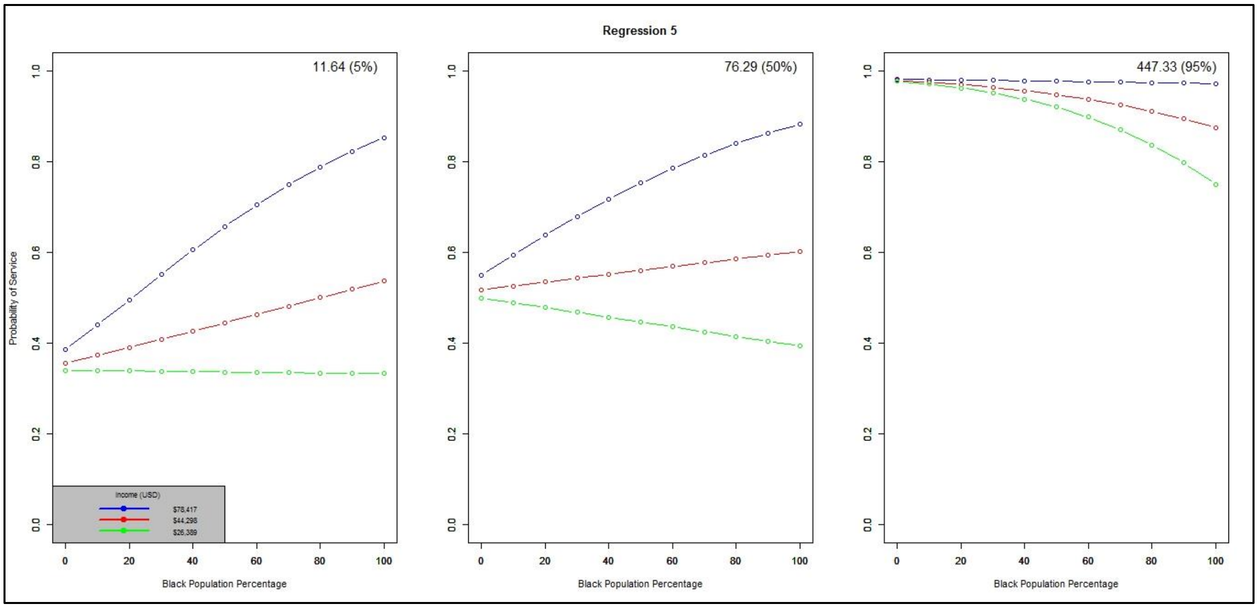

Figure 11: Regression 5 results of probability of water service in Catawba County
Housing density of each plot (and percentile) given at top right.

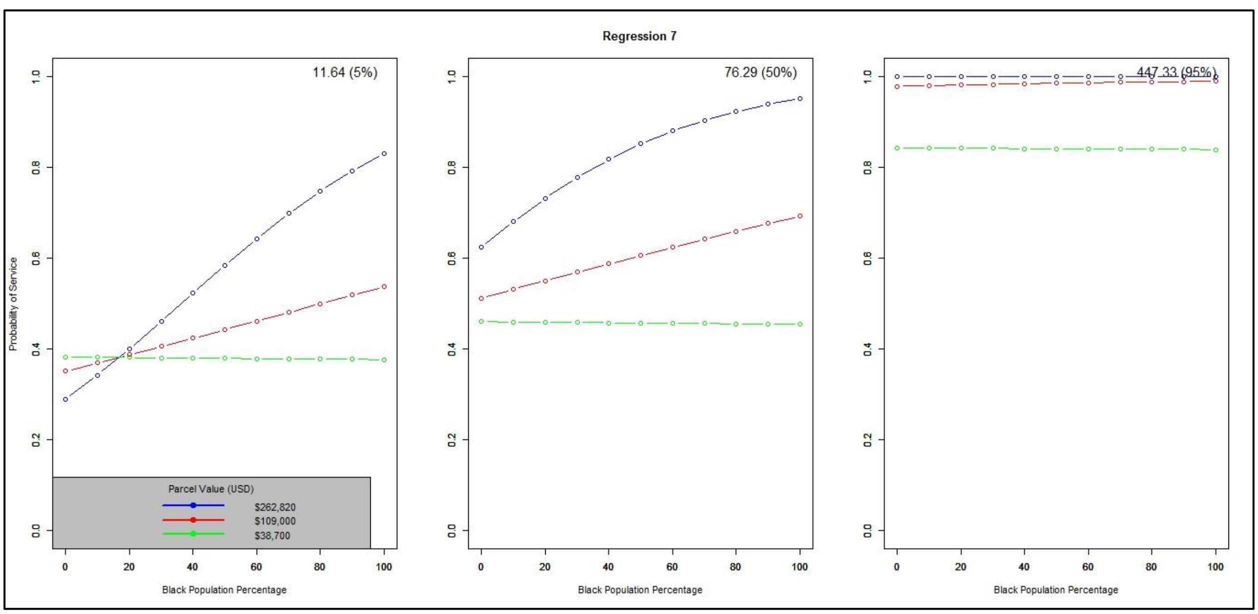

Figure 12: Regression 7 results of Catawba County water service probability, also regression of lowest AIC.
Housing density of each plot (and percentile) given at top right.

Regression 7 (R7, **Figure 12**), with respect to parcel value rather than income, had the lowest AIC value for predicting municipal water service in Catawba County. Trends in R7 are very similar to those observed in regression 5 (R5, **Figure 11**); trends of low socioeconomic status and low to median housing density (green, left and center plots) saw no change or slight decrease in service probability with an increase in black population percentage, while trends with median or high income or parcel values increased.

At 95th percentile housing density, both regressions predicted very high rates of service. However, R7 showed that change in black population percentage had little to no effect on service probability, though R5 showed small service probability decay for 5th and 50th percentile income trends (red, green, right plot). In each regression across all housing density levels, low socioeconomic status clearly resulted in the lowest service probability.

Term	Regression 5		Regression 7	
Race (R)	**-1.11E+00**	2.92E-01	**-4.56E-01**	3.21E-01
Socioeconomic (S)	**3.86E-06**	1.08E-01	**-2.75E-06**	1.40E-05
Housing Density (H)	**1.02E-02**	4.25E-89	**2.05E-03**	2.99E-02
RS Interaction	**4.34E-05**	9.02E-02	**1.12E-05**	3.03E-02
RH Interaction	**-6.12E-03**	1.03E-01	**-**	-
SH Interaction	**-**	-	**7.50E-08**	8.42E-18
RSH Interaction	**-**	-	**-**	-
Intercept	**-8.82E-01**	7.46E-13	**-4.31E-01**	2.23E-06
AIC	**5197.9**		**5096.9**	

Table 9: Coefficients (left column) and p-values (right column) of each regression used in the Catawba County – water pairing. Statistically significant p-values ($p < 0.05$) in red.

For R5 only the housing density (H) term was statistically significant. R7 had 4 significant terms: parcel value, housing density, percent black – parcel value interaction, and parcel value – housing density interaction (**Table 9**). R5 and R7 coefficient signs only disagree for the S term, though the difference is not noticeable in overall trends – higher socioeconomic status is associated with higher probability of service across all scenarios.

Major differences between regressions occur at high housing density (**Figures 11 and 12**, right plots). R7 feels negligible impact of changes in black population percentage, while R5 shows a clear drop in service with rise in black population percentage. In R7, the rise in R and its negative term coefficient is offset by influence of an increasingly positive SH interaction term. R5 includes an RH interaction term that becomes increasingly negative, leading to an overall drop in service at high R and H levels.

Catawba – Sewer Pairing

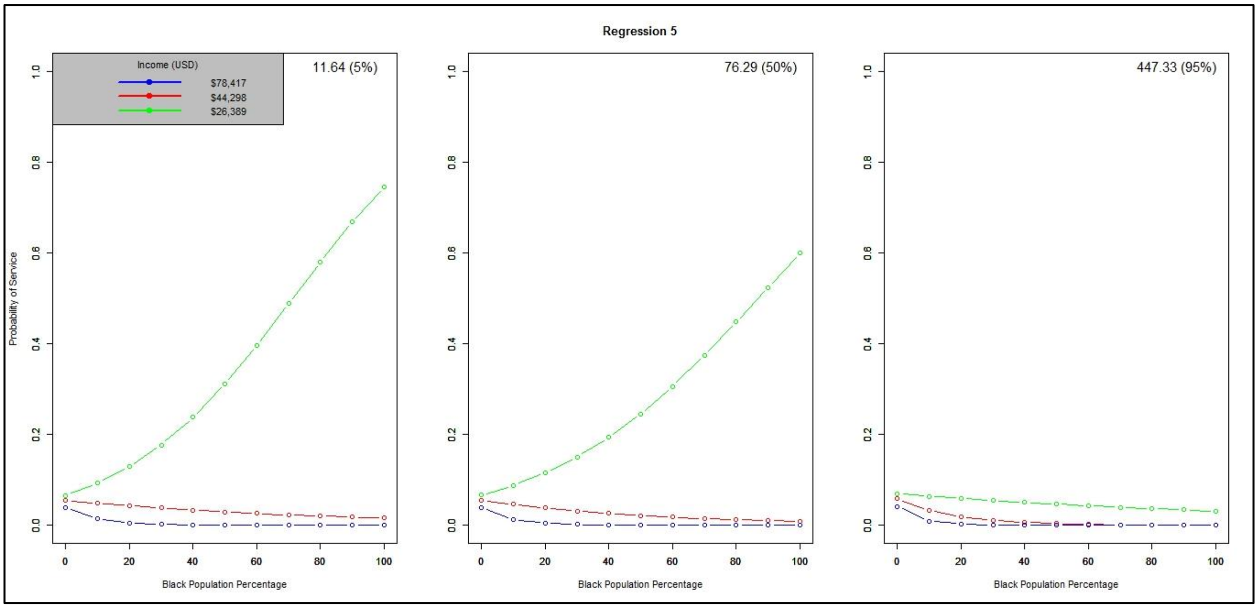

Figure 13: Regression 5 results of probability of sewer service in Catawba County
Housing density of each plot (and percentile) given at top right.

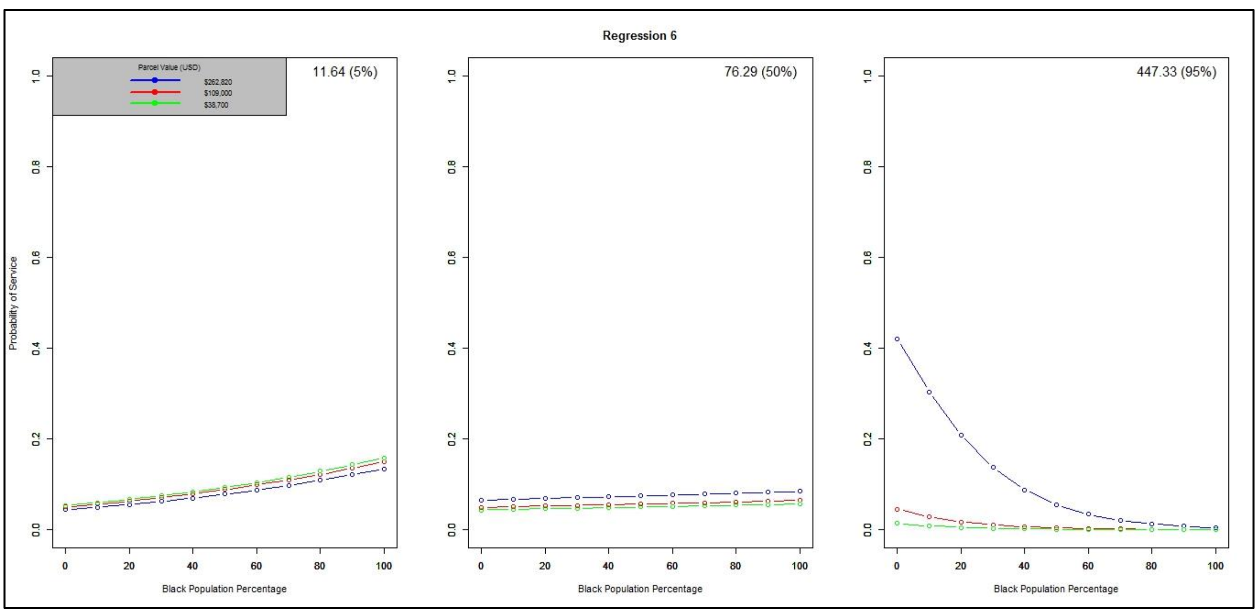

Figure 14: Regression 6 results of Catawba County sewer service probability, also regression of lowest AIC.
Housing density of each plot (and percentile) given at top right.

Regression 6 (R6, **Figure 14**), including parcel value rather than income, was the model of lowest AIC for Catawba County sewer service prediction. Both regression 5 (R5. **Figure 13**) and 6 forecast very low service probability for median and 95th percentile socioeconomic levels across all black population percentages. At 5th and 50th percentile housing density, R5 predicts large increases in service for low income populations with increasing black population percentage, but this was not evident in R6 with parcel values.

Term	Regression 5		Regression 6	
Race (R)	**1.13E+01**	1.37E-04	**1.38E+00**	3.19E-02
Socioeconomic (S)	**-1.06E-05**	6.36E-02	**-1.35E-06**	2.24E-01
Housing Density (H)	**1.29E-04**	8.44E-01	**-4.89E-03**	1.18E-03
RS Interaction	**-2.81E-04**	4.40E-04	**-**	-
RH Interaction	**-1.05E-02**	9.28E-02	**-1.44E-02**	2.13E-02
SH Interaction	**-**	-	**4.26E-08**	3.80E-05
RSH Interaction	**-**	-	**-**	-
Intercept	**-2.38E+00**	1.93E-19	**-2.79E+00**	5.23E-51
AIC	**1793.4**		**1789.3**	

Table 10: Coefficients (left column) and p-values (right column) of each regression used in the Catawba County – sewer pairing. Statistically significant p-values ($p < 0.05$) in red.

Two terms, percent black population and percent black – income interaction, of R5 were significant. However, percent black, housing density, percent black – housing density interaction, and parcel value – housing density interaction terms were significant in R6 (**Table 10**).

Notable differences between R5 and R6 include the difference in housing density term coefficient sign, though it is difficult to see with overall low service probability. Both regressions do predict a drop in service probability with an increase in black population percentage at high housing density; this can be attributed to negative coefficients of the RS and RH terms of both regressions.

Discussion and Conclusions

While it is apparent that race, socioeconomics, and housing density have complex interactions with water and sewer service in both counties, it is difficult to identify one variable alone as an accurate indicator of municipal water or sewer service probability.

Regressions including interaction terms between race, socioeconomic, and housing density variables show lower predicted water service in areas of high housing density for majority black populations than majority white populations in both counties. However, in low or median housing density scenarios, Burke County water service probability for low-income and medium-income communities increases as black population percentage increases; this is opposite the trends of low-income and median-income communities in low or median housing density levels in Catawba County. In the high housing density scenarios for water service in Burke County, the regressions shown did not agree; one showed general decrease in service with increasing black population, the other a decrease.

Municipal sewer service probability trends were quite different from those of water service. Burke County regressions agreed that low-income, majority-black communities in areas of low-to-median housing density had higher access to service than white communities of the same status. At high housing density, the two regressions chosen for comparison completely disagree. Catawba County results saw some agreement between regression 5 and the regression of lowest AIC. Overall sewer access is very low for all areas, though low-income, low-to-median housing density, majority black communities appear to have higher probability of service than similar, majority white areas. The models disagree in high housing density areas.

When considering regression 5 alone, as it is comparable across both counties, some general trends appear. In Burke County, all income levels see a decrease in water service at high housing density, but sewer service decreases only for median and high income levels in this case. Catawba County access to both water and sewer decreases with increasing black population percentage for low-income groups at all housing density levels, as well as for all income levels at high housing density.

The differences in access may be a reflection of socioeconomic status in each county. Catawba County has an overall higher socioeconomic standing (**Tables 2,3**), but median ETJ parcel values and incomes are lower than the county medians. The opposite trend in Burke County could point to Burke ETJs not only containing low-income, minority communities, but also those of higher-income residents perhaps intentionally living outside of the municipality for tax benefits.

Furthermore, we must consider the difference between displayed regressions and how those changes are expressed. Regressions 0a, 2, 5, 6, and 7 (**Tables 7-10**) all differ in which interaction terms are included. A particularly interesting difference is between regressions 2 and 5 of the Burke – Water regression analysis. Regression 5 only contains interaction terms with race, while regression 2 has only a socioeconomic and housing density interaction term. The two models agree generally at low and medium housing densities, but contrast at high housing density, which could point to housing density playing a larger role in predicting probability of service than race does. The housing density terms in 7 of the 8 regressions studied above were statistically significant.

It should also be mentioned that the data sources involved have unavoidably contributed to uncertainty in the results. Tax parcel data from both counties are updated at least every 8 years according to NC General Statute 105-286. However, Burke County last evaluated real property in the county in 2013, and land value of a parcel is estimated based on neighborhood sampling averages (http://www.burkenctax.com/_fileUploads/files/ 2013%20SCHEDULE%20OF%20VALUES.pdf). Catawba County parcels were last appraised in 2011 (http://www.catawbacountync.gov/tax/Revaluation.asp). Furthermore, Burke County tax parcel data "UTIL" code only displays a maximum of 3 utility services available to a parcel; unless the parcel has all available utility services and is coded with a "1", a parcel could have water, sewer, electric, and gas services, but only three will be shown. It is possible that a property could thus be labeled as having no water or sewer service when in fact it does.

Not only do these datasets differ temporally from the 2010 Census information used here, but there is also spatial disagreement. Using census block and block group data to investigate parcel-level trends inevitably introduces error. Perhaps future studies will have more robust data sources and be able to avoid such disparities in resolution.

Our results are suggestive of the fact that race could play a role in municipal water and sewer service access in Burke and Catawba County ETJs, but the magnitude and direction of impact greatly varies between socioeconomic and housing density scenarios. Specific analysis of the historical urban planning and zoning designations of areas of interest within these ETJs would be more illuminating in determining whether or not these communities still feel the influence of race-based segregation, but our results alone are not indicative of such discrimination.

If municipal water and sewer service information is not available, it may be possible to conduct a comparable study using existence of a well or septic system at the parcel level as a proxy for lack of municipal service. As well, though we did not discuss them in this paper, our methods can also be applied to studying non-white and Hispanic populations within ETJs. As North Carolina and the United States as a whole see an increase in Hispanic population, it will be interesting to see if other minority groups experience the same discrimination practices as blacks.

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APPENDIX I

```
def Find(field):
   if field.find('3') != -1 or field.find('1') != -1:
      return 1
   else:
      return 0
```

Figure 1: Python code for extracting sewer information from Burke County taxdata

```
def Find(field1, field2):
   if field1 == 'PUBLIC WATER' or field1 == 'ALL PUBLIC':
      return 1
   elif field2 == 'PUBLIC WATER':
      return 1
   else:
      return 0
```

Figure 2: Python code for extracting water information from Catawba County taxdata

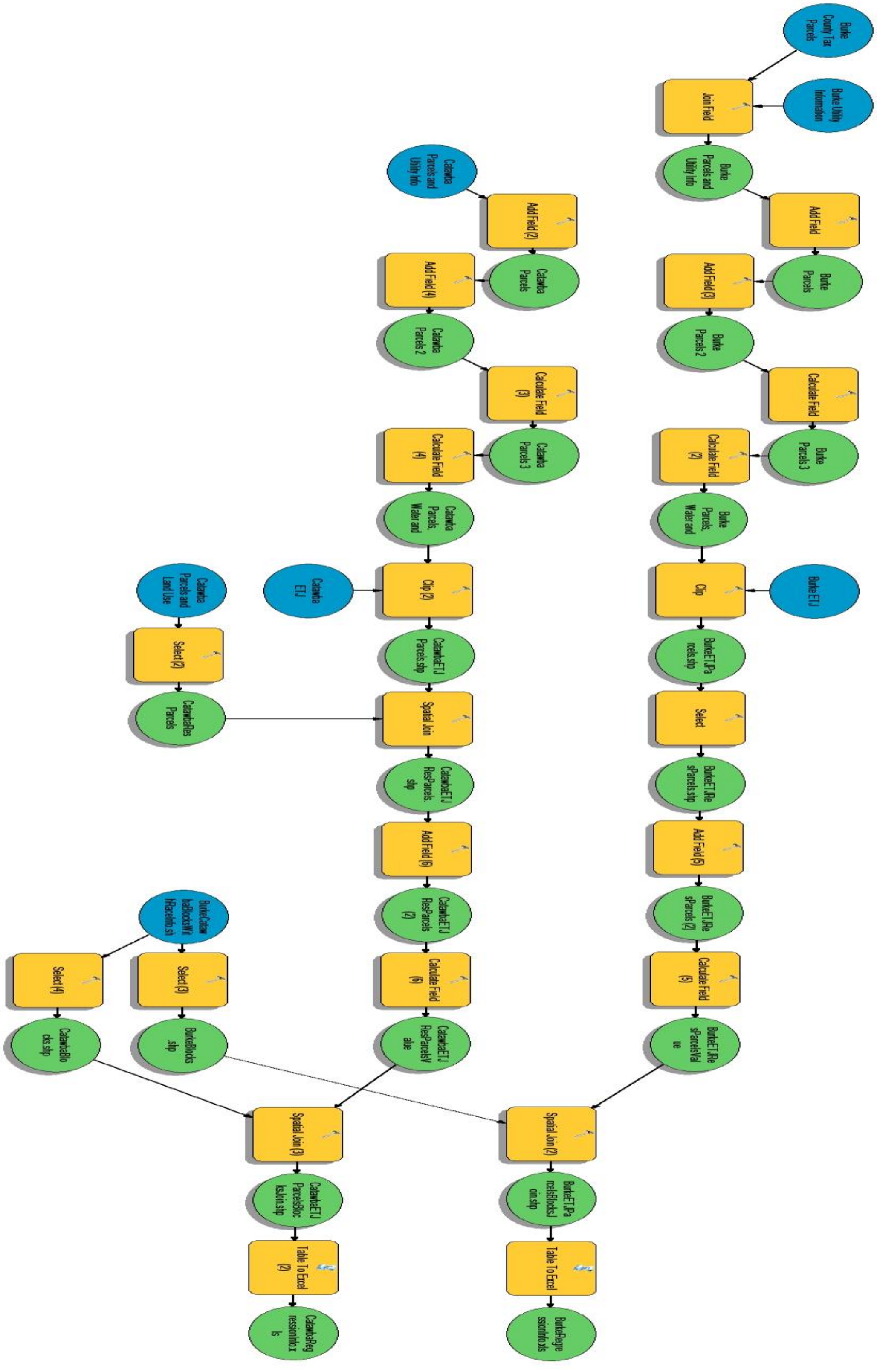

Figure 3: Flow chart of ArcGIS procedure.
Blue = data inputs, Orange = processes, Green = outputs